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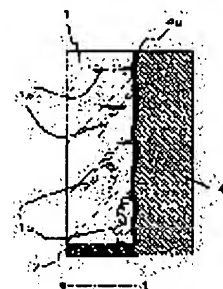
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(54) LAMINATED PIEZOELECTRIC ELEMENT, ITS MANUFACTURING METHOD, AND INJECTION EQUIPMENT USING IT

(57)Abstract:

PROBLEM TO BE SOLVED: To provide a laminated piezoelectric element excellent in durability, its manufacturing method, and a fuel injection equipment which prevents an external electrode from peeling from the lamination surface, even when a prolonged continuous drive is carried out under a high electric field and a high-pressure force.

SOLUTION: The laminated piezoelectric element is provided with a lamination which laminates two or more piezo electric elements and two or more internal electrodes alternately, and a pair of external electrode, wherein the internal electrode connected alternately, provided in the side of the layered product. The external electrode consists of a conducting material and glass, and a crack is provided in the piezoelectric element surface layer of the interface between the external electrode and the piezoelectric element, so that the crack may be filled with a glass material.



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DETAILED DESCRIPTION

[Detailed Description of the Invention]

[Field of the Invention]

[0001]

This invention relates to a fuel injection equipment at a laminating mold piezoelectric device and its process lists, such as a laminating mold electrostrictive actuator used for precision positioning devices, such as a piezoelectric transformer, and a fuel injection equipment for automobiles, optical equipment, the driver element for vibration isolation, etc. at a laminating mold piezoelectric device and its process list, concerning a fuel injection equipment.

[Background of the Invention]

[0002]

Conventionally, as a laminating mold piezoelectric device, the laminating mold electrostrictive actuator which carried out the laminating of a piezo electric crystal and the internal electrode by turns is known. When it is classified into two kinds such as a simultaneous baking type and the stack type which carried out the laminating of piezoelectric ceramics and the internal electrode plate by turns and takes into consideration in a laminating mold electrostrictive actuator from the field of low-battery-izing and manufacturing-cost reduction, since it is advantageous, a simultaneous baking type laminating mold electrostrictive actuator is showing the predominance to it to lamination.

[0003]

Drawing 5 shows the conventional laminating mold electrostrictive actuator, in this laminating mold electrostrictive actuator, the laminating of a piezo electric crystal 51 and the internal electrode 52 is carried out by turns, a layered product 53 is formed and the laminating of the inactive layer 55 is carried out to the ends side in that direction of a laminating. The external electrode 70 is formed in the side face of the layered product 53 which the edge of one of these had exposed the internal electrode 52 to the side face of a layered product 53 alternately with right and left, and the edge of this internal electrode 52 exposed. The other-end section of an internal electrode 52 is covered with an insulator 61, and is insulated in the external electrode 70.

[0004]

Moreover, the simultaneous baking type laminating mold electrostrictive actuator had obtained the layered product by calcinating, after degreasing at predetermined temperature about the laminate-molding object acquired by carrying out the number laminating of predetermined leaves of what printed the internal electrode paste which carried out addition mixing of the binder to silver-palladium powder to the ceramic green sheet which consists of the temporary-quenching powder and the organic binder of a piezo electric crystal.

[Description of the Invention]

[Problem(s) to be Solved by the Invention]

[0005]

However, in the conventional laminating mold electrostrictive actuator, when prolonged continuation actuation was carried out under high electric field and the high voltage force, the contact fault was no

longer supplied to the electrical potential difference by the piezo electric crystal of a lifting part in the connection of an external electrode and an internal electrode, and there was a problem that a displacement property changed at the time of actuation.

[0006]

Namely, although higher electric field are impressed and carrying out prolonged continuation actuation is performed in recent years in order to secure the big amount of displacement in the bottom of a big pressure by the small laminating mold electrostrictive actuator A conductive paste only by the ability to only be applied and burned on the side face of a layered product When continuation actuation was carried out by high electric field, without fully performing junction to an external electrode and an internal electrode, the external electrode may have exfoliated from the layered product side face and the internal electrode edge, the contact fault may have arisen, and the problem that a displacement property will fall may have arisen.

[0007]

This invention aims at providing with a fuel injection equipment the cheap laminating mold piezoelectric-device list which an external electrode and an internal electrode were not disconnected and was excellent in endurance, even when prolonged continuation actuation is carried out under high electric field and the high voltage force.

[Means for Solving the Problem]

[0008]

The layered product which comes to carry out the laminating of two or more piezo electric crystals and two or more internal electrodes in the laminating mold piezoelectric device of this invention by turns, It is the laminating mold piezoelectric device which comes to provide the external electrode of a couple by which it was prepared in the side face of this layered product, and said internal electrode was connected by turns for setting further. Said external electrode consists of electric conduction material and glass, a crack is prepared in the piezo electric crystal surface section of the interface of this external electrode and said piezo electric crystal, and it is characterized by filling up this crack with a glass ingredient.

[0009]

Moreover, said glass ingredient is characterized by being the same component as the glass which constitutes said external electrode.

[0010]

Moreover, it is characterized by preparing said crack in said piezo electric crystal surface section 100 micrometers or less in the depth direction from said interface.

[0011]

Moreover, it is characterized by the filling factor of the glass ingredient under said crack being 70% or more.

[0012]

Moreover, it is characterized by forming a glass layer in said layered product and said external inter-electrode one.

[0013]

On the other hand, the manufacture approach of the laminating mold piezoelectric device of this invention It is prepared in the side face of the layered product which comes to carry out the laminating of two or more piezo electric crystals and two or more internal electrodes by turns, and this layered product. It is the manufacture approach of a laminating mold piezoelectric device of coming to provide the external electrode of a couple by which said internal electrode was connected by turns for setting further. Grinding of said external electrode forming face of said layered product is carried out with a grinding stone coarser than #6000. The electric conduction material paste which contains the glass which has softening temperature lower than the temperature which can be burned in said external electrode more than 1 mass %, and it can be burned and is sometimes contracted the 10% or more of the thickness directions can be burned, and it is characterized by including the process which forms said external electrode.

[0014]

Moreover, the fuel injection equipment of this invention is characterized by coming to provide the stowage container which has a nozzle, the laminating mold piezoelectric device of above-mentioned this invention held in this stowage container, and the bulb which gushes a liquid from said nozzle by actuation of this laminating mold piezoelectric device.

[Effect of the Invention]

[0015]

Thus, the layered product which comes to carry out the laminating of two or more piezo electric crystals and two or more internal electrodes by turns according to the laminating mold piezoelectric device of this invention, It is the laminating mold piezoelectric device which comes to provide the external electrode of a couple by which it was prepared in the side face of this layered product, and said internal electrode was connected by turns for setting further. By said external electrode's having consisted of electric conduction material and glass, having prepared the crack in the piezo electric crystal surface section of the interface of this external electrode and said piezo electric crystal, and having filled up this crack with the glass ingredient While said glass ingredient and the glass which constitutes said external electrode join with sufficient compatibility Since the glass ingredient with which said crack was filled up can improve said piezo electric crystal and bonding strength according to the wedge effectiveness in said piezo electric crystal, When said external electrode is firmly joined by said layered product side face and continuation actuation is carried out by high electric field, it can prevent the problem that said external electrode exfoliates from a layered product side face arising.

[0016]

Moreover, since glass can be simultaneously filled up into said crack with the process which can be burned in said external electrode while strengthening more the junction force of said external electrode and said piezo electric crystal by being the same component as the glass with which said glass ingredient constitutes said external electrode, the number of production processes can be reduced and it is not necessary to add a new glass ingredient.

[0017]

Moreover, while becoming easy to fill up said crack with a glass ingredient by having prepared said crack in said piezo electric crystal surface section 100 micrometers or less in the depth direction from said interface, the destruction from said crack can be controlled with the stress generated inside said piezo electric crystal.

[0018]

Moreover, while being able to reduce the destruction produced from said crack by continuation actuation of a laminating mold piezoelectric device when the filling factor of the glass ingredient under said crack is 70% or more, the junction force of said external electrode and said piezo electric crystal can be strengthened more.

[0019]

Moreover, since the glass which constitutes said external electrode by having formed the glass layer in said layered product and said external inter-electrode one, and said glass ingredient are firmly joined through said glass layer, the bonding strength of said external electrode and said piezo electric crystal can be raised easily.

[0020]

Moreover, since the fuel injection equipment possessing the stowage container which has a nozzle, the above-mentioned laminating mold piezoelectric device held in this stowage container, and the bulb which gushes a liquid from said nozzle by actuation of this laminating mold piezoelectric device can control an open circuit with the external electrode of said laminating mold piezoelectric device, and an internal electrode, it can improve endurance substantially under high electric field.

[Best Mode of Carrying Out the Invention]

[0021]

Drawing 1 shows one example of a laminating mold electrostrictive actuator which consists of laminating mold piezoelectric devices of this invention, (a) is a perspective view and (b) is a side elevation.

[0022]

The laminating mold electrostrictive actuator which consists of a laminating mold piezoelectric device of this invention. In the side face of the layered product 10 of the shape of the square pole which carries out the laminating of two or more piezo electric crystals 1 and two or more internal electrodes 2 by turns, and becomes as shown in drawing 1. The external electrode 4 which consists of electric conduction material which uses silver as a principal component, and glass is joined to the edge of the internal electrode 2 which covers with an insulator 3 to set the edge of an internal electrode 2 further, and has not been covered with an insulator 3, and connection immobilization of the lead wire 6 is carried out, and it is constituted by each external electrode 4.

[0023]

Although the internal electrode 2 is arranged between piezo electric crystals 1, this internal electrode 2 is formed with metallic materials, such as silver-palladium, impresses a predetermined electrical potential difference to each piezo electric crystal 1, and has the operation which makes a piezo electric crystal 1 start the variation rate by the inverse piezoelectric effect.

[0024]

On the other hand, since the inactive layer 9 is a layer of two or more piezo electric crystals 1 with which the internal electrode 2 is not arranged, even if it impresses an electrical potential difference, it does not start a variation rate.

[0025]

Moreover, the external electrode 4 is joined by the side face in which a layered product 10 counters, and since the internal electrode 2 by which the laminating is carried out is electrically connected to this external electrode 4 to set further, an electrical potential difference required to carry out the variation rate of the piezo electric crystal 1 according to an inverse piezoelectric effect can be supplied to each internal electrode 2 connected in common.

[0026]

Furthermore, since connection immobilization of the lead wire 6 is carried out with solder etc. at the external electrode 4, the external electrode 4 is connectable with an external electrical-potential-difference feed zone.

[0027]

And the external electrode 4 consisted of electric conduction material and glass, prepared crack 1a in the piezo electric crystal 1 surface section of the interface of the external electrode 4 and a piezo electric crystal 1, and has filled up the glass ingredient with the laminating mold electrostrictive actuator of this invention into this crack 1a. If crack 1a with which the glass ingredient was filled up into the piezo electric crystal 1 surface section does not exist, since this will stop easily being able to join the external electrode 4 and a piezo electric crystal 1 firmly, if it carries out long duration continuation actuation of the laminating mold piezoelectric device, the external electrode 4 will exfoliate from a layered product side face, a contact fault will arise, and a displacement property will fall.

[0028]

On the other hand, in the laminating mold electrostrictive actuator of this invention, since the glass ingredient with which crack 1a was filled up, and the glass which constitutes the external electrode 4 can join with sufficient compatibility, junction to the external electrode 4 and a piezo electric crystal 1 can be made firm according to the wedge effectiveness over the piezo electric crystal 1 of a filler. Here, as shown in drawing 2 (a), when the glass which constitutes the external electrode 4 joins the above-mentioned wedge effectiveness to the glass ingredient within the crack which has the structure which drove the wedge into the piezo electric crystal 1, the bonding strength to the piezo electric crystal 1 of the external electrode 4 becomes strong. It can have the outstanding endurance, without the external electrode 4 exfoliating from layered product 10 side face by this, when carrying out prolonged continuation actuation under high electric field and the high voltage force.

[0029]

In addition, as shown in drawing 2 (a), even if the sense of a crack is vertical and it inclines to the interface of the external electrode 4 and a piezo electric crystal 1, it is not cared about. Moreover, the

head of crack 1a may reach the internal electrode 2, and it does not matter even if crack 1a is progressing from the internal electrode 2 side.

[0030]

Since crack 1a can be filled up with temperature lower enough than the burning temperature of a piezo electric crystal 1 by combining and controlling the softening temperature of the glass ingredient with which crack 1a is filled up, property change of a piezo electric crystal 1 can be controlled.

[0031]

The above-mentioned glass ingredient consists of ingredients which use glass as a principal component, and silica glass, soda lime glass, lead alkali silicic-acid glass, alumino way silicic-acid salt glass, way silicic-acid salt glass, alumino silicic-acid salt glass, way acid chloride glass, phosphoric acid salt glass, lead glass, etc. are used for it as a glass component.

[0032]

For example, it is crazy, and it can be and zero to 10 mass % and the thing of which alkali-metal oxide 0-10 mass % content is done can be used for 240 to SiO₇₀ mass %, 2O₃₀ to B-2 O₃₂ - 30 mass % aluminum₂₀ mass %, and an alkaline-earth-metal oxide like MgO, CaO, SrO, and BaO in a total amount as acid chloride glass. Moreover, the above-mentioned one silicic-acid salt glass is not cared about as glass which contains ZnO of 5 - 30 mass %. ZnO is effective in it being crazy, being and reducing the working temperature of acid chloride glass.

[0033]

Moreover, as phosphoric acid salt glass, glass which contains 2O₅₄₀ to P₈₀ mass %, 2O₃₀ to aluminum₃₀ mass %, 30 to B-2O₃₀ mass %, zero to ZnO₃₀ mass %, zero to alkaline-earth-metal oxide 30 mass %, and the alkali-metal oxide 0 - 10 mass % can be used.

[0034]

Moreover, as lead glass, glass which contains 30 to PbO₈₀ mass %, 20 to SiO₇₀ mass %, 2O₃₀ to Bi₃₀ mass %, 2O₃₀ to aluminum₂₀ mass %, zero to ZnO₃₀ mass %, zero to alkaline-earth-metal oxide 30 mass %, and the alkali-metal oxide 0 - 10 mass % can be used.

[0035]

Moreover, in order to raise the above-mentioned compatibility, as for the glass ingredient with which the glass which constitutes the external electrode 4, and a crack are filled up, it is desirable that it is the presentation which has an equivalent principal component.

[0036]

In addition, about the existence of the glass with which crack 1a was filled up, and the filling factor of the glass with which crack 1a mentioned later was filled up, it can check by field analysis of the glass configuration element in EPMA (electron ray probe minute partial analysis).

[0037]

Furthermore, it is desirable that it is the same component as the glass with which the glass ingredient with which crack 1a was filled up constitutes the external electrode 4. Since this can fill up glass into crack 1a with the process which can be burned in the external electrode 4 simultaneously while strengthening more the junction force of the external electrode 4 and a piezo electric crystal 1 by using the same glass component, it can reduce the number of production processes.

[0038]

Furthermore, it is desirable to prepare crack 1a in the piezo electric crystal 1 surface section 100 micrometers or less in the depth direction t from the interface of the external electrode 4 and a piezo electric crystal 1. This is because it progresses to the depths from the piezo electric crystal surface section, and the origin of destruction may come or crack 1a may disconnect an internal electrode 2 while stopping easily being able to fill up crack 1a with a glass ingredient, if crack 1a is prepared in the piezo electric crystal 1 surface section which exceeded 100 micrometers in the depth direction t from said interface. In addition, measurement of the die length of crack 1a observed and asked for the cross section of the arbitration of the piezo electric crystal 1 surface section joined to the external electrode 4 in SEM (scanning electron microscope). In addition, the scale factor made 2000 times and a measurement part ten places.

[0039]

Furthermore, it is desirable for the filling factor of the glass ingredient in crack 1a to be 70% or more. Since the junction force of the glass which constitutes the external electrode 4 as a filling factor is less than 70%, and the glass ingredient in crack 1a becomes weak, exfoliation of the external electrode 4 may produce this from a layered product 10. Moreover, since the opening part with which a glass ingredient is not filled up into crack 1a increases, if long duration continuation actuation is carried out, stress concentration arises into this opening part, and a layered product 10 may break.

[0040]

Furthermore, it is desirable to form a glass layer between the side face of a layered product 10 and the external electrode 4. The glass which constitutes the external electrode 4, and the glass ingredient of 1 within crack a can join it firmly through said glass layer while the glass ingredient which constitutes said glass layer can enter and fill up crack 1a with this, if said glass layer is formed.

[0041]

Furthermore, drawing 4 shows the fuel injection equipment which consists of a laminating mold piezoelectric device of this invention, and has the stowage container 31 which has a nozzle 33, the electrostrictive actuator 43 held in this stowage container 31, and the bulb 35 which gushes a liquid from a nozzle 33 by actuation of this electrostrictive actuator.

[0042]

The fuel path 37 is established in a nozzle 33 possible [a free passage], this fuel path 37 is connected with an external fuel source, and the fuel is always supplied to the fuel path 37 with fixed high voltage. Therefore, if a bulb 35 opens a nozzle 33, it is formed so that the fuel currently supplied to the fuel path 37 may be spouted in the combustion chamber which an internal combustion engine does not illustrate with fixed high voltage.

[0043]

Moreover, the diameter is large and the upper bed section of a bulb 35 serves as the cylinder 39 and the piston 41 on which it can be slid which were formed in the stowage container 31.

[0044]

In such a fuel injection equipment, if an electrical potential difference is impressed to an electrostrictive actuator 43 and it develops, a piston 41 will be pressed, a needle valve 35 will blockade a nozzle 33, and supply of a fuel will be suspended. Moreover, if impression of an electrical potential difference is stopped, an electrostrictive actuator 43 will contract, the pan spring 45 pushes back a piston 41, a nozzle 33 is open for free passage with the fuel path 37, and injection of a fuel is performed.

[0045]

The piezo electric crystal 1 is formed with the electrostrictive ceramics ingredient which uses titanate lead zirconate $\text{Pb}(\text{Zr}, \text{Ti})\text{O}_3$ (it omits Following PZT) or barium titanate BaTiO_3 as a principal component. As for this electrostrictive ceramics, what has the piezo-electric high distortion constant d_{33} which shows that piezo-electric property is desirable.

[0046]

Moreover, the thickness of a piezo electric crystal 1, i.e., the distance between internal electrodes 2, has desirable 50-250 micrometers. Thereby, it can prevent dielectric breakdown of a piezo electric crystal 1 while it can perform miniaturization of a laminating mold electrostrictive actuator, and low back-ization, even if a laminating mold electrostrictive actuator increases the number of laminatings, in order to impress an electrical potential difference and to obtain the bigger amount of displacement.

[0047]

The remainder became the electric conduction material 80 which uses silver as a principal component - 99 mass % from one to glass component 20 mass %, and the external electrode 4 has mainly joined the side face of the piezo electric crystal 1 of a layered product 10 through the glass component in the external electrode 4. Moreover, although the external electrode 4 can be burned in the electric conduction material paste which consists of electric conduction material and glass and is formed, it is desirable for it to be burned and to sometimes contract 10% or more in the thickness direction of the external electrode 4. By being burned and sometimes shrinking an electric conduction material paste in

the thickness direction 10% or more, this can make the piezo electric crystal 1 surface section able to generate crack 1a in the stress by contraction when burned, and can be grown up into crack 1a which has the magnitude which is extent into which a glass ingredient can enter the minute crack which exists in the piezo electric crystal 1 surface section beforehand.

[0048]

The component of the glass which constitutes the external electrode 4 has desirable glass of 800 degrees C or less of softening temperatures which raise bonding strength with a piezo electric crystal 1, and contain at least one sort of lead oxide or oxidation silicon in an effective target from the point of filling up a crack. Moreover, silica glass, soda lime glass, lead alkali silicic-acid glass, alumino way silicic-acid salt glass, way silicic-acid salt glass, alumino silicic-acid salt glass, way acid chloride glass, phosphoric acid salt glass, lead glass, etc. are used for a glass component in addition to the above-mentioned.

[0049]

For example, it is crazy, and it can be and zero to 10 mass % and the thing of which alkali-metal oxide 0-10 mass % content is done can be used for 240 to SiO₇₀ mass %, 2O₃₀ to B-2 O₃₂ - 30 mass % aluminum 20 mass %, and an alkaline-earth-metal oxide like MgO, CaO, SrO, and BaO in a total amount as acid chloride glass. Moreover, the above-mentioned one silicic-acid salt glass is not cared about as glass which contains ZnO of 5 - 30 mass %. ZnO is effective in it being crazy, being and reducing the working temperature of acid chloride glass.

[0050]

Moreover, as phosphoric acid salt glass, glass which contains 2O₅₄₀ to P₈₀ mass %, 2O₃₀ to aluminum 30 mass %, 30 to B-2O₃₀ mass %, zero to ZnO 30 mass %, zero to alkaline-earth-metal oxide 30 mass %, and the alkali-metal oxide 0 - 10 mass % can be used.

[0051]

Moreover, as lead glass, glass which contains 30 to PbO 80 mass %, 20 to SiO₇₀ mass %, 2O₃₀ to Bi 30 mass %, 2O₃₀ to aluminum 20 mass %, zero to ZnO 30 mass %, zero to alkaline-earth-metal oxide 30 mass %, and the alkali-metal oxide 0 - 10 mass % can be used.

[0052]

Moreover, the electric conduction agent which constitutes an external electrode has oxidation resistance, its Young's modulus is low, and it is desirable to use silver as a principal component from the point of being cheap. In addition, the platinum or palladium of a minute amount may be added from the point of raising electromigration-proof nature.

Furthermore, the slot with a width of face [of a depth of 30-500 micrometers and the direction of a laminating] of 30-200 micrometers is formed in the side face of a layered product 10 setting further, this Mizouchi is filled up with glass, an epoxy resin, polyimide resin, polyamidoimide resin, silicone rubber, etc., and the insulator 3 is formed. In order to strengthen junction to a layered product 10, it is suitable for this insulator 3 that the elastic modulus followed to the variation rate of a layered product 10 consists of a low ingredient, especially silicone rubber, etc.

[0053]

Next, the process of a laminating mold electrostrictive actuator which consists of a laminating mold piezoelectric device of this invention is explained.

[0054]

The laminating mold electrostrictive actuator of this invention first mixes the temporary-quenching powder of electrostrictive ceramics, such as PZT, the binder which consists of organic giant molecules, such as acrylic and a butyral system, and plasticizers, such as DBP (phthalic-acid geotail) and DOP (dibutyl phthalate), produces a slurry, and produces the ceramic green sheet which serves as a piezo electric crystal 1 by tape-forming methods, such as a doctor blade method of common knowledge of this slurry, and the calendering roll method.

[0055]

Next, a binder, a plasticizer, etc. carry out addition mixing of the temporary-quenching powder of said electrostrictive ceramics etc. at silver-palladium powder if needed, the conductive paste which forms an internal electrode 2 is produced, and this is printed in thickness of 1-40 micrometers by screen-stencil

etc. on the top face of each of said green sheet.

[0056]

And after carrying out two or more sheet laminating of the green sheet with which the conductive paste was printed by the top face and performing a debinder at predetermined temperature about this layered product, a laminating baking object is produced by calcinating at 900-1200 degrees C.

[0057]

In addition, a laminating baking object is not limited to what is produced by the above-mentioned process, and as long as it can produce the laminating baking object which comes to carry out the laminating of two or more piezo electric crystals 1 and two or more internal electrodes 2 by turns, it may be formed of what kind of process.

[0058]

Grinding attachment, such as a surface grinder, performs grinding for the acquired laminating baking object with a grinding stone coarser than #6000, and the layered product 10 of a predetermined dimension is obtained. A very small crack is formed in the layered product 10 surface section at this time. This very small crack serves as an origin, and crack 1a can be formed in the piezo electric crystal 1 surface section of the joint of a piezo electric crystal 1 and the external electrode 4 at the time of formation of the external electrode 4 mentioned later.

[0059]

Then, as shown in drawing 3 (a), the concave 5 with a width of face [of a depth of 30-500 micrometers and the direction of a laminating] of 30-200 micrometers is formed for setting further on the side face of a layered product 10 with dicing equipment etc.

[0060]

Next, the formation approach of the external electrode 4 is explained.

[0061]

First, a binder is added to the mixture which consists silver powder with a particle size of 0.1-10 micrometers of 80 - 99 mass % and one to glass powder 20 mass % in which the remainder contains at least one or more sorts of lead oxide or oxidization silicon by 0.1-10 micrometers, and the electric conduction material paste 21 is produced.

[0062]

And on the film which carried out mold release processing, the electric conduction material paste 21 is screen-stenciled by the thickness of 5-40 micrometers, and the electric conduction material paste sheet 21 is exfoliated from a mold releasing film after desiccation. At this time, it is desirable to carry out the fine-particles filling factor which set the silver powder and glass powder of the electric conduction material paste 21 after desiccation 40 to 75%. The external electrode 4 can be formed by imprinting this electric conduction material paste sheet 21 to external electrode 4 forming face of the layered product 10 in which the slot was formed as shown in drawing 3 (b), and burning at temperature higher than the softening temperature of the glass component contained in the electric conduction material paste 21, and the temperature below the silver melting point.

[0063]

Crack 1a formed of the above-mentioned grinding process here While growing up with the stress by contraction of the electric conduction material paste at the time of baking The glass components which the glass component under electric conduction material paste 21 is filled up into crack 1a with the temperature field beyond the softening temperature of the glass contained in the electric conduction material paste 21 by capillarity, and are simultaneously contained in the electric conduction material paste 21 gather for the surface section of a piezo electric crystal 1 selectively, and glass layer 4a is formed. At this time, the glass component with which crack 1a was filled up, and glass layer 4a formed in the piezo electric crystal 1 surface section are joined firmly mutually. That is, the glass component of the external electrode 4 has structure which drove the wedge into the piezo electric crystal 1 surface section, and connection between a result, the external electrode 4, and a layered product 10 becomes a positive firm thing.

[0064]

The silver in the external electrode 4 carries out counter diffusion to the silver-palladium which constitutes an internal electrode 2, and an internal electrode 2 and the external electrode 4 make it join firmly at this time.

[0065]

in order [moreover,] to form a glass layer in the interface of the external electrode 4 and a piezo electric crystal 1 at an effective target -- the electric conduction material paste 21 -- multilayer structure -- or dip may be attached to distribution of the glass component under electric conduction material paste 21. That is, by making [many] the glass component, it can be burned, a glass component invades into the crack of the piezo electric crystal 1 surface section sometimes effectively, and glass layer 4a can be formed in the interface of a piezo electric crystal 1 and the external electrode 4, so that a piezo electric crystal 1 surface section side is approached.

[0066]

Moreover, it can be burned even if it prepares glass layer 4a in the piezo electric crystal 1 surface section, and it does not matter in the phase of the electric conduction material paste 21 even if it sometimes prepares glass layer 4a between a layered product 10 and the external electrode 4. Also in this case, since a glass component has bad internal electrode 2 and wettability which were exposed from layered product 10 side face, it can be burned and the silver under electric conduction material paste 21 is sometimes firmly joined by the silver-palladium and diffused junction which form an internal electrode 2.

[0067]

In addition, the formation approach of the external electrode 4 is not limited to an above-mentioned approach, and may be printed to external electrode 4 forming face of direct layered product 10 side face.

[0068]

Moreover, as for the electric conduction material paste 21, it is desirable for it to be burned and to sometimes contract 10% or more in the thickness direction. This can form crack 1a in an effective target with the stress by contraction when burned by making contraction into 10% or more at the piezo electric crystal 1 surface section.

[0069]

Here, contraction shows by the percentage what could be burned with the desiccation thickness of the electric conduction material paste 21, and broke the difference of next thickness by desiccation thickness.

[0070]

In addition, contraction of the thickness direction at the time of baking of the electric conduction material paste 21 is possible for forming, even if there is no minute crack in the above-mentioned grinding operation, and in order to form crack 1a by contraction of an electric conduction material paste, it is desirable [contraction] for said contraction to be 20% or more.

[0071]

Moreover, as internal electrode 2 head which carries out diffused junction to the silver in the external electrode 4 is pulled by the external electrode 4 and it is shown in drawing 2 (b), crack 1a on the basis of an internal electrode 2 arises, and this crack 1a may be filled up with a glass ingredient by contraction of the electric conduction material paste 21.

[0072]

Moreover, as for the thickness of the external electrode 4, it is desirable that it is thinner than the thickness of a piezo electric crystal 1. Also in order to follow still more preferably telescopic motion of the layered product which is a body of an actuator, 50 micrometers or less are more desirable.

[0073]

Having made glass powder of 80 to 99 mass % and the remainder into one to 20 mass % the silver powder under electric conduction material paste When there is less silver powder than 80 mass %, the specific resistance of the external electrode 4 becomes large, and when passing a high current and making it drive at high speed, local heat may be produced with this external electrode 4. By one side

When there is more silver powder than 99 mass %, a glass component may decrease relatively, the bonding strength of the external electrode 4 and a layered product 10 may become weak, and the problem that the external electrode 4 will exfoliate from a layered product 10 during actuation may arise.

[0074]

Moreover, bonding strength with a layered product 10 can be raised by making the glass component of an electric conduction material paste contain at least one sort of lead oxide or silicon oxide.

[0075]

Next, by immersing the layered product 10 in which the external electrode 4 was formed in a silicone rubber solution, and carrying out the vacuum deairing of said silicone rubber solution, the concave 5 interior of a layered product 10 is filled up with the insulating layer 3 which consists of silicone rubber, a layered product 10 is pulled up from a silicone rubber solution after that, and the side face of a layered product 10 is coated with silicone rubber. Then, the concave 5 interior is made to harden said silicone rubber with which restoration and layered product 10 side face were coated.

[0076]

Then, the laminating mold electrostrictive actuator which consists of a laminating mold piezoelectric device of this invention is completed by connecting lead wire 6 to the external electrode 4 with solder etc.

[0077]

in addition, range ***** which does not deviate from this invention, without limiting the laminating mold electrostrictive actuator using the laminating mold piezoelectric device of this invention to the example mentioned above -- it is deformable. For example, although the concave 5 which filled up the insulator 3 with **** is formed, you may be the configuration which can maintain insulation which the edge of an internal electrode 2 is joined to the external electrode 4 by setting further, and another edge of an internal electrode 2 does not join to the external electrode 4 like the electrode takeoff connection of the conventional laminating mold ceramic condenser.

[0078]

And by impressing the direct current voltage of 0.1-3kV/mm to the external electrode 4 of a couple through lead wire 6, and carrying out polarization processing of the layered product 10 If the laminating mold electrostrictive actuator as a product is completed, lead wire 6 is connected to an external electrical-potential-difference feed zone and an electrical potential difference is made to impress to an internal electrode 2 through lead wire 6 and the external electrode 4 Each piezo electric crystal 1 is greatly displaced according to an inverse piezoelectric effect, and functions on an engine by this as a fuel injection valve for automobiles which carries out injection supply of the fuel.

[Example]

[0079]

The laminating mold electrostrictive actuator which consists of a laminating mold piezoelectric device of this invention was produced as follows.

[0080]

First, the slurry which mixed the temporary-quenching powder of the electrostrictive ceramics which uses PZT as a principal component, the binder, and the plasticizer was produced, and the ceramic green sheet which becomes the piezo electric crystal 1 with a thickness of 150 micrometers with a doctor blade method was produced.

[0081]

The conductive paste which added the binder to the silver-palladium alloy was formed in one side of this green sheet by 3-micrometer thickness with screen printing, the 300-sheet laminating of said ceramic green sheet was carried out, it calcinated at 980-1100 degrees C, and the laminating baking object was acquired. Then, grinding of the laminating baking object was carried out using the grinding stone of #400, and the layered product 10 of drawing 1 was obtained. The very small crack had arisen in the piezo electric crystal 1 surface section of the obtained layered product 10.

[0082]

Next, as shown in drawing 3 (a), the slot with a depth [of 50 micrometers] and a width of face of 30 micrometers was formed for setting further at the edge of the internal electrode 2 of layered product 10 side face with dicing equipment.

[0083]

Next, the glass powder which contains at least one or more sorts of a lead oxide or silicon oxide in 80 - 99 mass % for silver powder with a mean particle diameter of 2 micrometers with the mean particle diameter of 2 micrometers was mixed, the binder was added further, and the electric conduction material paste was produced.

[0084]

Next, on the mold releasing film, it printed by the thickness of 5-40 micrometers by screen-stencil, the electric conduction material paste was removed from the mold releasing film after desiccation, and the silver paste sheet was obtained. The fine-particles filling factor of the silver paste sheet at this time was 55%. Then, said silver paste sheet was imprinted on the side face of a couple in which layered product 10 side face in which the slot was formed counters, and baking was performed at 800 degrees C for 15 minutes.

[0085]

At this time, glass layer 4a in which the glass component was unevenly distributed was formed in the piezo electric crystal 1 side surface section of the external electrode 4. Moreover, contraction of the thickness direction of the electric conduction material paste 21 was 40%. (The thickness after baking was 60% of dry thickness Mino.) Further, from observation of a cross-section photograph, with a die length of 5-20 micrometers crack 1a existed in the piezo electric crystal 1 surface section of a joint with the external electrode 4, and it filled up with the glass which constitutes the external electrode 4 in this crack 1a.

[0086]

Then, lead wire was connected to the external electrode, 3kV [/mm] direct-current electric field were impressed to the positive electrode and the external electrode of a negative electrode for 15 minutes through lead wire, polarization processing was performed, and the laminating mold electrostrictive actuator which consists of a laminating mold piezoelectric device of this invention shown in drawing 1 was produced.

[0087]

(Example 1) Except having changed the yarn count (granularity) of the grinding stone which carries out grinding of the laminating baking object, the class, and baking temperature of the conductive paste which constitutes the external electrode 4, the layered product electrostrictive actuator (sample numbers 1-5) which is the example of this invention was produced using the above-mentioned process.

[0088]

Moreover, grinding of the laminating sintered compact was carried out as an example of a comparison with the grinding stone which has the fine yarn count, and when [which constitute the external electrode 4] be burned and contraction produced the external electrode 4 using the very small conductive paste 21, the laminating mold electrostrictive actuator formed so that crack 1a might not be substantially prepared in the piezo electric crystal 1 surface section was produced (sample number 6). Moreover, in the laminating mold electrostrictive actuator of a sample number 6, the glass layer did not exist in the piezo electric crystal side 1 surface section of the external electrode 4.

[0089]

When the direct current voltage of 185V was impressed to the above-mentioned various laminating mold electrostrictive actuators, in all laminating mold electrostrictive actuators, the variation rate of 49 micrometers was obtained in the direction of a laminating. Furthermore, these laminating mold electrostrictive actuators were impressed at the room temperature, the alternating current electric field of 0-+185V were impressed on the frequency of 150Hz, and the actuation trial was performed up to 1x10⁶ cycle.

[0090]

In addition, in SEM, the existence of crack 1a observed 20 locations of arbitration, and judged the

interface of the external electrode 4 and a piezo electric crystal 1. Although the filling factor of the glass ingredient to the crack 1a section showed the rate of the area of the glass ingredient with which this crack 1a is filled up to the area of each crack 1a with the above-mentioned cross-section SEM photograph by the percentage, it showed the value with the lowest filling factor in a table 1 in inside. It combined and the existence of glass and a presentation were checked by field analysis by EPMA. Moreover, the depth of a crack was made into the thing of the greatest depth of the crack observed from the above-mentioned cross-section SEM photograph. The interface of the external electrode and piezo electric crystal same about the appearance after an actuation trial as the above-mentioned after an actuation trial was written about the result of having performed observation of the location of arbitration in SEM. The rate of change of the amount of displacement measured the amount of displacement after an actuation trial on the basis of the amount of displacement before an actuation trial, and computed the rate of the change. A result is shown in a table 1.

[A table 1]

No.	亀裂の有無	亀裂中のガラス材料充填率 (%)	亀裂の存在位置 (外部電極と圧電体の界面からの深さ) (μm)	1×10 ⁶ サイクル駆動後	
				外観	変位量の変化
1	有り	90	50	○	変化なし
2	有り	70	50	○	変化なし
3	有り	65	50	○	変化なし
4	有り	90	100	○	変化なし
5	有り	90	110	○	変化なし
*6	無し	—	—	数箇所剥離(外部電極)	40%低下

*を付した試料番号は本発明の請求範囲外のものである

[0091]

since crack 1a did not exist in the piezo electric crystal 1 surface section substantially from this table 1 in the laminating mold electrostrictive actuator of the sample number 6 which be an example of a comparison, since there be no ****, after 1x10⁶ cycle actuation, several external electrodes 4 exfoliated from the layered product front face, and the amount of displacement fell the wedge effectiveness with the glass mentioned above by the ability not fill up crack 1a with glass.

[0092]

On the other hand, the laminating mold electrostrictive actuator of the sample numbers 1-5 of this invention Since crack 1a was prepared in the piezo electric crystal 1 surface section of external electrode 4 joint, and this crack 1a was filled up with the glass ingredient and the external electrode 4 and the layered product front face were firmly joinable with the wedge effectiveness of the glass ingredient with which crack 1a was filled up The problem said that the amount of displacement falls did not arise without the external electrode 4 exfoliating from a layered product front face, when a laminating mold electrostrictive actuator is made to drive at high speed.

[0093]

Furthermore, it drove up to 1x10⁹ cycle on the same conditions as the above-mentioned. A result is shown in a table 2.

[A table 2]

No.	亀裂の有無	亀裂中のガラス材料 充填率(%)	亀裂の存在位置 (外部電極と圧電体 の界面からの深さ) (μm)	1×10^9 サイクル駆動後	
				外観	変位量の変化
1	有り	90	50	○	変化なし
2	有り	70	50	○	変化なし
3	有り	65	50	一部剥離(外部電極)	5%低下
4	有り	90	100	○	変化なし
5	有り	65	110	一部断線(内部電極)	10%低下
*6	無し	—	—	外部電極焼損	ショート不良

* を付した試料番号は本発明の請求範囲外のものである

[0094]

From this table 2, since the laminating mold electrostrictive actuator of a sample number 3 had the filling factor of the glass ingredient to crack 1a smaller than 70%, the wedge effectiveness by the glass ingredient became weak, the junction force of the external electrode 4 and a piezo electric crystal 1 declined, during actuation, some external electrodes 4 exfoliated from the layered product, and the amount of displacement fell.

[0095]

Moreover, since the laminating mold electrostrictive actuator of a sample number 5 had the depth of crack 1a larger than 100 micrometers, a part of crack 1a progressed, other crack 1a was reached, it becomes easy to form big crack 1a, crack 1a penetrated to some internal electrodes 2, the open circuit occurred, and the amount of displacement fell.

[0096]

As opposed to these the laminating mold electrostrictive actuator of sample numbers 1, 2, and 4 The depth of crack 1a by 100 micrometers or less in the interface of a piezo electric crystal 1 and the external electrode 4 - the depth direction t And since 70% or more of the crack is filled up with the glass ingredient, When long duration actuation is carried out at high speed, the external electrode 4 does not exfoliate from a layered product front face, and the problem that the amount of displacement falls has not arisen.

[Availability on industry]

[0097]

The laminating mold piezoelectric device of this invention can be used for a piezoelectric transformer. Moreover, the laminating mold piezoelectric device of this invention can be used for the laminating mold electrostrictive actuator used for precision positioning devices, such as a fuel injection equipment for automobiles, and optical equipment, the driver element for vibration isolation, etc. Furthermore, it can use for fuel injection equipments, such as automotive fuel and ink of an ink jet printer, by using the laminating mold piezoelectric device of this invention.

[Brief Description of the Drawings]

[0098]

[Drawing 1] The laminating mold piezoelectric device of this invention is shown, (a) is a perspective view and (b) is a side elevation.

[Drawing 2] (a) And (b) is an expanded sectional view in the piezo electric crystal surface section of the laminating mold piezoelectric device of this invention.

[Drawing 3] (a) - (c) is an explanatory view for explaining the process of the laminating mold piezoelectric device of this invention.

[Drawing 4] It is the side elevation showing the fuel injection equipment of this invention.

[Drawing 5] It is the side elevation of the conventional laminating mold electrostrictive actuator.

[Description of Notations]

[0099]

1 ... Piezo electric crystal

1a ... Crack

2 ... Internal electrode

3 ... Insulator

4 ... External electrode

4a ... Glass layer

5 ... Concave

6 ... Lead wire

10 ... Layered product

21 ... Electric conduction material paste

31 ... Stowage container

33 ... Nozzle

35 ... Bulb

43 ... Electrostrictive actuator

[Translation done.]

* NOTICES *

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CLAIMS

[Claim(s)]

[Claim 1]

It is prepared in the side face of the layered product which comes to carry out the laminating of two or more piezo electric crystals and two or more internal electrodes by turns, and this layered product. It is the laminating mold piezoelectric device which comes to provide the external electrode of a couple by which said internal electrode was connected by turns for setting further. The laminating mold piezoelectric device characterized by for said external electrode having consisted of electric conduction material and glass, having prepared the crack in the piezo electric crystal surface section of the interface of this external electrode and said piezo electric crystal, and filling up this crack with a glass ingredient.

[Claim 2]

The laminating mold piezoelectric device according to claim 1 characterized by being the same component as the glass with which said glass ingredient constitutes said external electrode.

[Claim 3]

The laminating mold piezoelectric device according to claim 1 or 2 characterized by preparing said crack in said piezo electric crystal surface section 100 micrometers or less in the depth direction from said interface.

[Claim 4]

The laminating mold piezoelectric device according to claim 1 to 3 characterized by the filling factor of the glass ingredient under said crack being 70% or more.

[Claim 5]

The laminating mold piezoelectric device according to claim 1 to 4 characterized by forming a glass layer in said layered product and said external inter-electrode one.

[Claim 6]

It is prepared in the side face of the layered product which comes to carry out the laminating of two or more piezo electric crystals and two or more internal electrodes by turns, and this layered product. It is the manufacture approach of a laminating mold piezoelectric device of coming to provide the external electrode of a couple by which said internal electrode was connected by turns for setting further. Grinding of said external electrode forming face of said layered product is carried out with a grinding stone coarser than #6000. The manufacture approach of the laminating mold piezoelectric device characterized by including the process which applies the electric conduction material paste which contained glass more than 1 mass %, is higher than the softening temperature of said glass, and can be burned at the temperature contracted the 10% or more of the thickness directions, and forms said external electrode.

[Claim 7]

The fuel injection equipment characterized by coming to provide in either the laminating mold piezoelectric device of a publication, and the bulb which gushes a liquid from said nozzle by actuation of this laminating mold piezoelectric device claim 1 held in the stowage container which has a nozzle, and this stowage container thru/or among 5.

[Translation done.]

* NOTICES *

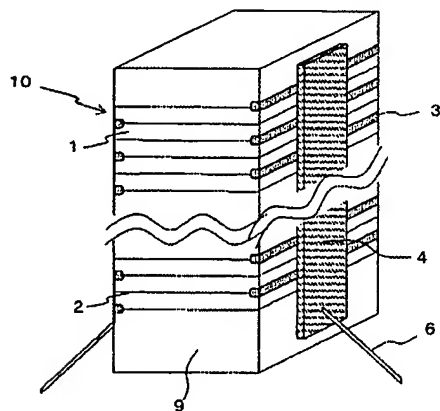
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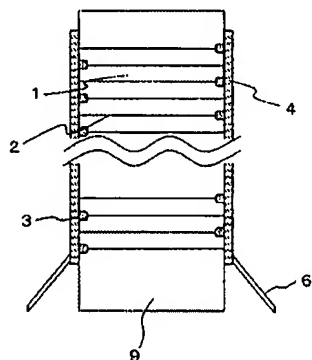
DRAWINGS

[Drawing 1]

(a)

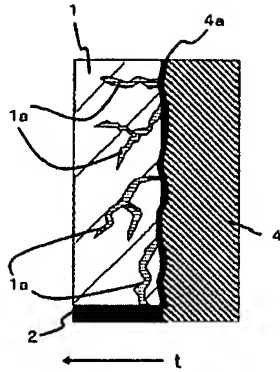


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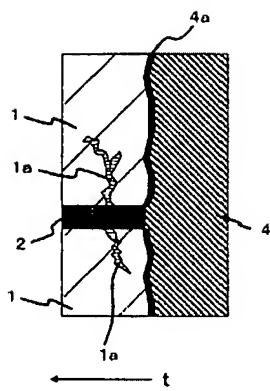


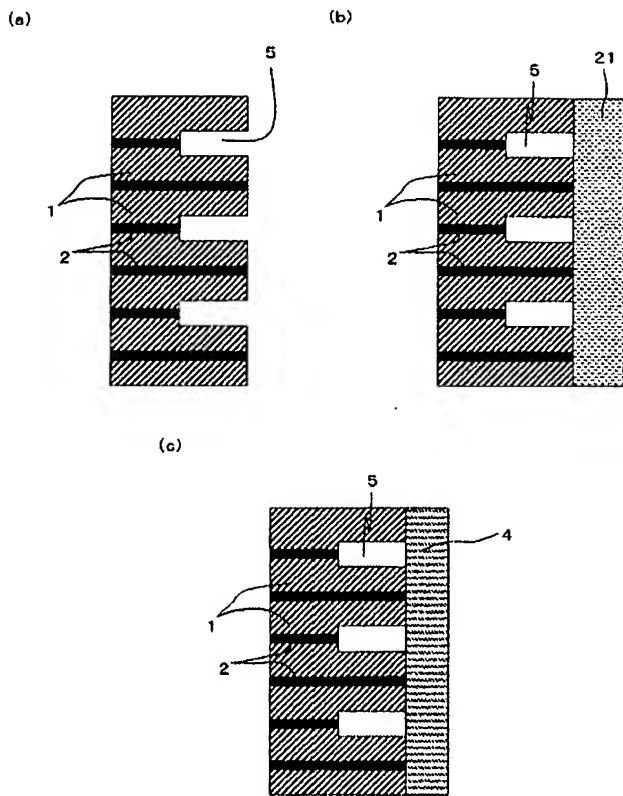
[Drawing 2]

(a)

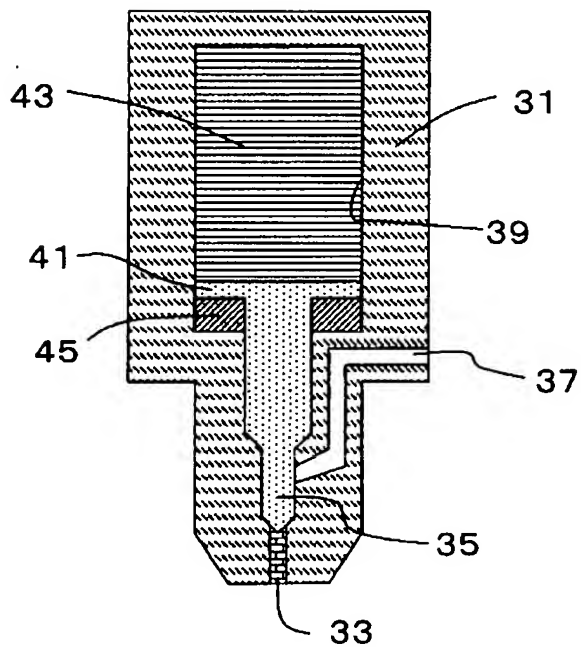


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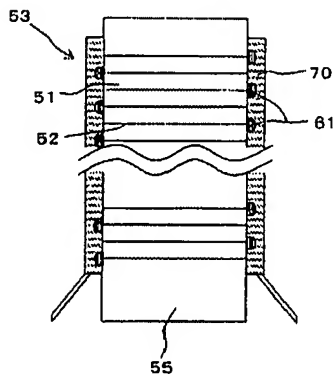
[Drawing 3]



[Drawing 4]



[Drawing 5]



[Translation done.]